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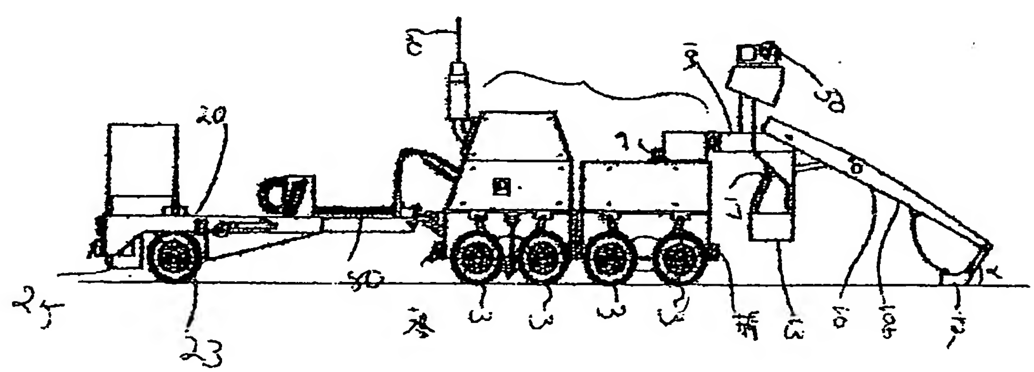
(54) **VEHICULE DE DETECTION DE MINES TERRESTRES**
(54) **LANDMINE DETECTION VEHICLE**



(57) The present invention relates to a vehicle for use in detecting landmines. The vehicle is remotely controlled and includes a variety of sensing apparatus disposed to scan a path at least the width of the vehicle. The vehicle is provided with path markers for indicating scanned path width, sensors for determining potential landmines and other sensors for use in confirming landmine locations. Individuals then follow the system and detonate or excavate landmines at the determined locations.

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Abstract of the Disclosure

The present invention relates to a vehicle for use in detecting landmines. The vehicle is remotely controlled and includes a variety of sensing apparatus disposed to scan a path at least the width of the vehicle. The vehicle is provided with path markers for indicating scanned path width, sensors for determining potential landmines and other sensors for use in confirming landmine locations. Individuals then follow the system and detonate or excavate landmines at the determined locations.

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Landmine Detection Vehicle

Field of the Invention

This invention relates generally to automated landmine detection systems. In particular the invention relates to a remote controlled vehicle provided with a plurality of different sensors for use in determining landmine locations along a path of travel.

Background of the Invention

Humanitarian land mine removal (that is complete manual minefield clearing) involves very time consuming and dangerous human excavation of a field. Currently a simple hand prodder with a short metal probe is used to investigate surface soils "by feel" for objects. If an object is encountered by the prod having a characteristic size and depth, it must be carefully excavated to determine whether it is a mine. In the case of a mine, it will be defused or detonated. In practice, however, many objects are painstakingly excavated which are not mines, but rocks, pieces of metal or other material. Metal detectors may be used to locate metal objects, however, many mines are not metal, but plastic or even wood.

Minimum metal content (MMC) mine detectors having a search head and circuitry for detecting buried non-metallic and metallic land mines are well known. For example, United States patent number 4,016,486 in the name of Pecori assigned to the United States of America by the Secretary of the Army, discloses such circuitry. An MMC detector includes electronic circuitry to assist a human operator to determine the nature of a solid obstruction encountered below the surface of the ground. Typically, metals and rocks are distinguished from one another. Metals are potential land mines. A prodder capable of distinguishing threats, from non-threats reduces stress and fatigue of a human operator and speeds up the process of clearing an area of buried land mines. The search head is typically a UHF balanced bridge detector which is unbalanced by passing the search head over a soil area which has a dielectric constant different from the background. Such a condition exists when passing over a mine.

Currently, instrumented prodders are known having ultrasonic means in the form of an ultrasonic transducer at or near the probe tip that are used for characterization of buried obstructions; this device can be used in conjunction with an MMC detector wherein the MMC detector first detects the presence of metal within or about the ground indicating the vicinity of a land mine, and, wherein the instrumented prodder is used to probe the earth in the vicinity of the suspected land mine, the location of which may have been isolated using the MMC detector.

The critical problem for reliable performance of the acoustic probe is often the human user and user error. Errors of this type result from a high stress environment and prolonged work. Further, many false landmine excavations performed within a day may result in sloppiness and exhaustion. Reducing the number of excavations required to remove landmines from an area is therefore highly advantageous.

In order to reduce human error, it is beneficial to more accurately locate, identify, and confirm landmine locations prior to excavation. Minimum metal detectors are used for this purpose. Unfortunately, nails, bullet shells, pins, and so forth are all identified as containing metal. This results in many false landmine locations.

In locating explosives, thermal neutron activation sensors are commonly used. A sensor of this type focuses a neutron beam toward a potential explosive to determine the composition of the potential explosive. Devices such as TNAs are well known, however, due to cost and fragility, it is unlikely that such a device is useable in a minefield. A landmine detonation would destroy the TNA device and because a TNA device is expensive, this is not desirable.

It would be advantageous to provide a mechanism for accurately detecting landmines prior to commencing excavation of the landmines. It would also be advantageous detect landmine locations absent human exposure to the dangers of a minefield.

Summary of the Invention

It is therefore an object of the invention to provide a method and device, which overcome the aforementioned problems, related to hand held landmine detection units and humans provided with the units walking within minefields in order to locate landmines.

It is a further object of invention to provide a vehicle for detecting landmines located within a travel path of said vehicle.

Accordingly, the present invention comprises a vehicle having a plurality of wheels each wheel independently driven and provided with low ground pressure; an articulating arm for supporting a plurality of sensors, the sensors for sensing a presence of an indication of a potential landmine, the sensors further for sensing the presence across a substantially complete path of the vehicle; and a trailer portion having a sensor for determining with greater likelihood that a sensed indication is indicative of a presence of a landmine.

It is an advantage of the present invention that detection of potential landmine sites is automated.

It is a further advantage of the present invention that a small number of potential landmines require prodding and/or human excavation.

These and further advantages will be apparent to persons of skill in the art with reference to the following detailed description and exemplary drawings.

Brief Description of the Drawings

Exemplary embodiments of the invention will now be described in conjunction with the drawings, in which:

Fig. 1 is a side elevational view of a vehicle according to the invention comprising a chassis, an articulating arm having sensors disposed thereon, and a trailer;

Fig. 2 is a top view of a vehicle according to the invention comprising a chassis, an articulating arm having sensors disposed thereon, and a trailer;

Fig. 3 is a top view of a vehicle according to the invention comprising a chassis, an articulating arm having sensors disposed thereon, and a trailer, the vehicle traversing a curved path; and,

Fig. 4 is a simplified diagram of a thermal neutron activation sensor.

Detailed Description

A vehicle according to the invention is designed for use in land mine detection. For this purpose, it is preferable that the vehicle is tele-operated - remotely controlled. The vehicle is provided with features to protect it against landmine damage. These features include means for detecting and avoiding landmines, means for protecting at least some equipment from damage due to landmine explosions in close proximity to the vehicle, and means for maintaining mobility of the vehicle after it is damaged by a landmine explosion.

One method of controlling the vehicle remotely is using a spread spectrum data link. The use of such a data link provides enhanced security for the communication. The communication link employed is designed to not interfere with the sensors while in use. Those of skill in the art know to select remote control systems that would not affect the sensor systems in order to maintain control and functionality of the vehicle.

In use, a plough vehicle ploughs the ground to form a path. The plough detonates many landmines and levels the ground within reasonable limits. The detection vehicle according to the present invention follows the plow detecting locations of potential landmines. A third vehicle follows behind with the operators of the detection vehicle. The operators maintain a safe distance from the detection vehicle so as to ensure human safety. Once landmines are located and confirmed, humans are deployed to excavate or explode them. The result is a faster and more efficient landmine removal procedure.

Referring to Figs. 1 and 2, top and side views of a vehicle according to the invention are shown. The vehicle comprises a main chassis 1 (shown as 1A and 1B in Fig. 1). The chassis 1 is supported by a plurality of wheels 3 in the form of eight wheels. Each wheel 3 is independently driven. Providing power to eight wheels independently

results in a vehicle wherein a loss of a small number of wheels does not affect mobility. Of course, any number of wheels 3 may be employed. Optionally, treads are used instead of wheels 3. Further optionally, the wheels 3 are driven using sensors such that only a number of the wheels 3 are driven at a given time.

The chassis 1 is segmented along its length. In the drawings, the chassis is shown divided into two sections 1A and 1B with a pivotal connection therebetween. This allows the vehicle chassis 1 to traverse a narrow path when turning. When more wheels 3 are used, it is often preferable to divide the chassis 1 into further sections. This is discussed below with reference to Fig. 3.

The drive mechanism for the vehicle is designed to provide mobility and steering capability when wheels 3 are lost. Of course, the wheels that are lost are not known a priori so, preferably, the drive mechanism is flexible. This is accomplished using a computer controlled drive mechanism provided with feedback from the wheels. The feedback is used to determine a wheel's status. Examples of wheel status include engaging ground, not engaging ground, damaged, functioning properly, and so forth.

The chassis 1 supports several compartments each compartment for maintaining equipment at desired levels of safety and in desired environmental conditions. The rear housing 5B houses an engine, a power generator, a heating system, a cooling system, hydrostatic and drive motors (not shown). These components are well known in the art of vehicular design. The front housing 5A is climate controlled and houses temperature sensitive equipment such as computers, electronics, and so forth.

At a fore end of the chassis 1F, an articulating arm 10 is pivotally attached at pivot 7F. The articulating arm 10 is moved through an arc about the pivot 7F by a piston 9. The piston also acts to prevent the articulating arm 10 from swinging randomly along the arc when the vehicle is in motion. The articulating arm 10 extends from of the vehicle. On the arm 10 are disposed sensors such as, minimum metal detection sensors 12 and ground penetrating radar sensors 13 for sensing information indicative of potential landmines. This information is used to determine landmine locations and to steer the vehicle. When processing of the information takes longer than the time allotted for

making steering decisions, a statistical algorithm is employed to rapidly assess a likelihood that a detected item is in fact a landmine. Alternatively, the vehicle is stopped until a determination is made. The sensors 12 and 13 disposed on the arm 10 are positioned so as to sense indications of landmines. For example, ground penetrating radar sensors 13 are positioned a distance from the ground as shown in Fig. 2. Minimum metal detectors 12 are positioned so as to be in close proximity to the ground. In this configuration, each sensor operates accordingly. Of course, when a sensor is designed for use at a particular distance from the ground, it is preferable that the sensor be supported at that height.

The sensors detect indications of landmines in the ground beneath the articulating arm 10. Examples of indications include metal content, objects with a radar cross section within a known range, etc. The sensors 12 and 13 are disposed upon the arm 10 so as to sense indications across the complete path of the vehicle prior to the main chassis 1 and the wheels 3 of the vehicle traversing said path. This provides additional security against landmine explosions beneath the vehicle. When sensors 12 and/or 13 are temperature sensitive, cooling and/or heating are brought from the rear compartment out to the sensors.

The articulating arm is provided with a support section 10a and a boom 10b. The boom 10b is hingedly mounted on the support 10a and is capable of being lowered toward the ground or raised therefrom. Raising the boom allows for swinging of the entire articulating arm about the pivot point avoiding ground level obstructions. In a second position, the boom is raised to lay flat on top of the sections 1 for transport and storage. A drive mechanism 17 allows precision control of the boom 10a by a controller located at a remote location from the vehicle. Since, as indicated above, some sensors are intended for use within close proximity to the ground, these sensors are mounted at a forward end of the boom 10a and are lowered toward the ground during sensing. The sensors 12 are raised to avoid obstacles. Preferably, this occurs automatically during forward motion through selection of the angle α. More preferably, the boom will clear obstacles as large as one foot in height. The minimum metal detectors are then lowered toward the ground upon passing such an obstacle. Lowering of the boom and the sensors

occurs naturally due to the effects of gravity. Alternatively, the boom is biased toward the ground by a biasing mechanism such as a spring or a piston. Optionally, for use on uneven terrain the boom 10a is provided with means for controlling tilt as well.

The arm 10 supports several sensing devices in the form of minimum metal detectors (MMD) 12, ground penetrating radar (GPR) 13, forward looking infrared (FLIR) camera(s) 50, and video camera(s) for assistance in vehicle steering and control. The boom also supports lights and protective shielding for the sensors in the form of ballistic armor formed of composite materials. The articulated arm is also constructed from composite materials such as fiberglass selected so as not to influence sensing results. As is evident to those of skill in the art, a boom constructed of metal is detected by an MMD. Preferably, the material selected has low metal content and has an insignificant radar cross section.

The vehicle is provided with very low ground pressure in order to limit the types of landmines that may detonate because of the vehicles motion. For example, antitank mines are not detonated but personnel mines may be detonated. Personnel mines have less explosive charge and therefore are less likely to damage an armored vehicle. Preferably armor is used to protect the two compartments 1A and 1B.

On the vehicle is disposed an antenna for receiving control information and for transmitting sensor information. Typically the antenna is used for communications with the third vehicle carrying the operators.

Also on the vehicle is disposed a lane marking system 70. The lane marking system leaves an indication of the swept path. Referring to Fig. 3, since curved paths result in a reduced swept path width, this reduces likelihood of errors in determining the swept area. The reduced swept path width results from the sensors 12 and 13 not being exactly perpendicular to the direction of motion of the entire vehicle. The lane marking system 70 identifies the swept path width and the markers move outward and inward in dependence upon the radius of curvature of the vehicular motion.

The vehicle according to the present invention is particularly useful for detecting anti-tank mines which are only detonated by heavy forces approximating a tank weight. Once a plow has cleared an area of most anti-personnel mines, the area is relatively safe for the low pressure wheels of the vehicle and for manual mine clearing. With sensing and thus greater certainty of the location of mines, final clearing is made safer and quicker. An operator following the vehicle with remote drive control means will review the responses from the detectors. Common mine position patterns may be recognized by the operator prior to advancing the vehicle over the mine area. The vehicle can be stopped while manual clearing occurs. Alternatively, the location may be marked and evasive steering made to avoid driving over potentially dangerous mine areas until further clearing is done.

A trailer 20 is pulled behind the vehicle and attached thereto by a pivotal connection such as a trailer hitch. The trailer is provided with driven wheels 23. The wheels 23 operate in a not driven mode during vehicle motion. The wheels 23 of the trailer 20 are designed to turn and thereby provide steering of the trailer 20 during vehicular motion. Preferably, the trailer maintains a position within a path sensed by the sensors and determined to be "safe." This path is known as the swept path. As the turning radius of the vehicle decreases, the swept path width must increase in order to ensure that the trailer remains within the swept path. Alternatively, the trailer is also provided with a controlled pivot angle to maintain the trailer in a fixed relation to the chassis 1 and thereby maintain the trailer within the swept path. Preferably the trailer has a minimal width to increase the ease within which it is maintained within the swept path.

When a potential land mine is detected, the trailer 20 is advanced to a location near the detected potential landmine. The trailer is then shifted into a driven wheel mode where the wheels are driven. The tongue and groove 80 is unlatched allowing for the trailer 20 to move in line with the path of motion of the vehicle. When the vehicle is stopped, the steering of the wheels 23 allow for accurate positioning of the trailer. Once accurately positioned, the tongue and groove 80 is locked to provide additional stability for the trailer 20. On the trailer is mounted an explosive sensor in the form of a thermal neutron activation sensor (TNA) 25.

Once the TNA is disposed near the potential landmine the TNA 25 is lowered to about 6 centimeters above ground level for detection of explosive material beneath the ground. A neutron beam is focused toward the ground where the landmine may be. The sensor results indicate a likelihood that explosives are located in the present TNA location. When explosives are detected using the TNA 25, the explosives are exploded or excavated by personnel once the vehicle has moved.

In order to focus the neutron beam toward the ground, the bottom of the trailer 20 is either provided with an opening or with a neutron beam permeable material. Because of the cost of TNA 25, it is preferable to protect the sensor 25 from explosions, stones, and so forth. Therefore it is preferred that the bottom of the TNA 25 is protected by armor capable of withstanding a significant landmine detonation. It has been found that about 1 inch of armor is useful for this purpose. Unfortunately, using a commonly available TNA sensor which is best positioned 2-2.5 inches from the ground, uneven ground and other obstacles make its use less than effective when an inch of armor is attached to the bottom end of the sensor 25. Therefore, according to the present invention, the armor is incorporated within the TNA sensor 25 either as the base itself or above the base in order to maintain the sensor clearance at 2-2.5 inches. Even with this clearance, the TNA 25 is sometimes awkward to operate due to uneven ground.

Historically, people operated these devices near landmines without armor. This is easily understood since detonation of a landmine that would damage the device would also damage the person and hence was avoided. Using the present invention, threats to people are reduced at the landmine detection stage and, therefore, it is important to provide adequate protection for the TNA 25. Unfortunately, because the TNA 25 is activated very close to the ground, it bears a significant blast should a mine detonate below the trailer 20. Therefore, a suitable amount of armor is used.

Typically the trailer 20 moves a small amount on its own power using a fine motor which is not engaged during normal operation. In an embodiment, the trailer 20 has one meter of give but remains attached to chassis 1 during use.

Preferably, the vehicle control system controls the articulating arm and the trailer automatically with reference to the chassis 1 such that each portion of the vehicle traverses a path within the swept path and following the plough. As such, complicated steering of multiple vehicles simultaneously is avoided and operators can track other factors such as problems, sensor output, potential landmine locations, and so forth. Steering systems of this type are well known in the field of robotic control systems for mobile robots. Reference to works in that field will provide solutions for implementing such a system.

Referring to Fig. 4, a simplified diagram of a thermal neutron activation sensor 25 is shown. The nuclear source 103 is housed in a lead-lined box 104. This protects from radiation emissions and allows handling of the device. A base of the device 105 is formed of ballistic armor. Selection of a ballistic armor from those available and having a low impedance to a neutron beam is performed through experimentation. The use of ballistic armor protects against TNA damage and thereby prevents loss of expensive equipment and damage to handlers and the environment caused by radioactive material spills. Typically, the base 105 is a replacement of a base of a commercially available TNA 25. Alternatively, the armor is disposed within the lead-lined box above the base but below the nuclear source 103. Optionally, the sides of the TNA are also covered with armor to protect against landmine explosions.

Of course, numerous other embodiments may be envisaged, without departing from the spirit and scope of the invention.

Claims

What is claimed is:

1. A vehicle for detecting the presence of landmines comprising:
a plurality of wheels each wheel independently driven and provided with low ground pressure;
an arm for supporting a plurality of sensors in advance of the plurality of wheels in the direction of travel, the sensors for sensing a presence of an indication of a potential landmine; the sensors further for sensing the presence across a substantially complete path of the vehicle.

2. A vehicle for detecting the presence of landmines as defined in claim 1 wherein the supported sensors comprise minimum metal detectors

3. A vehicle for detecting the presence of landmines as defined in claim 1 or 2 wherein the supported sensors further comprise ground penetrating radar sensors.

4. A vehicle for detecting the presence of landmines as defined in claim 1 further including a trailer portion having a sensor for determining with greater likelihood that a sensed indication is indicative of a presence of a landmine.

5. A vehicle for detecting the presence of landmines as defined in claim 4 wherein the trailer portion comprises a thermal neutron activation sensor.

6. A vehicle for detecting the presence of landmines as defined in claim 1, wherein the vehicle includes means for remote controlled steerable drive.

7. A vehicle for detecting the presence of landmines as defined in claim 6, wherein the arm is articulated for raising and lowering the sensors and for added steering control.

8. A vehicle for detecting the presence of landmines as defined in claim 7, wherein the trailer includes a driven articulation to follow the vehicle path and to provide added steering control.

9. A vehicle for detecting the presence of landmines as defined in claim 1 comprising lane markers for marking a path width swept by the sensors.

10. A vehicle for detecting the presence of landmines as defined in claim 1 wherein the vehicle width across the path is narrower than a path width swept by the sensors.

11. A method of automatically detecting the presence of potential landmines comprising the steps of:
plowing a section of ground;
traversing the ground with a remote controlled vehicle comprising a plurality of different sensors, the sensors for sweeping an area across a width of the plowed section to detect indications of landmines in locations; and,
using a further sensor, analysing at least some of the locations to determine with a greater level of certainty whether each indication is an indication of a presence of a landmine.

12. A method as defined in claim 11 comprising the step of marking the swept area.

13. A method as defined in claim 11 wherein the plurality of different sensors comprises ground penetrating radar and minimum metal detection sensors.

14. A method as defined in claim 11 wherein the further sensor is a thermal neutron activation sensor.

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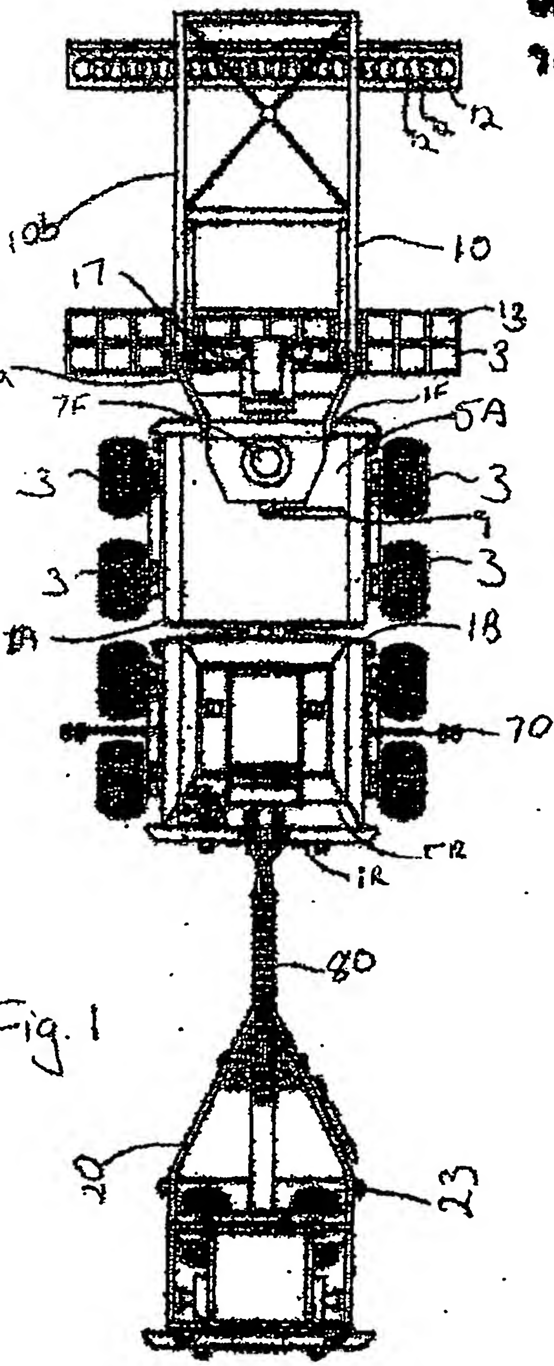

Fig. 1

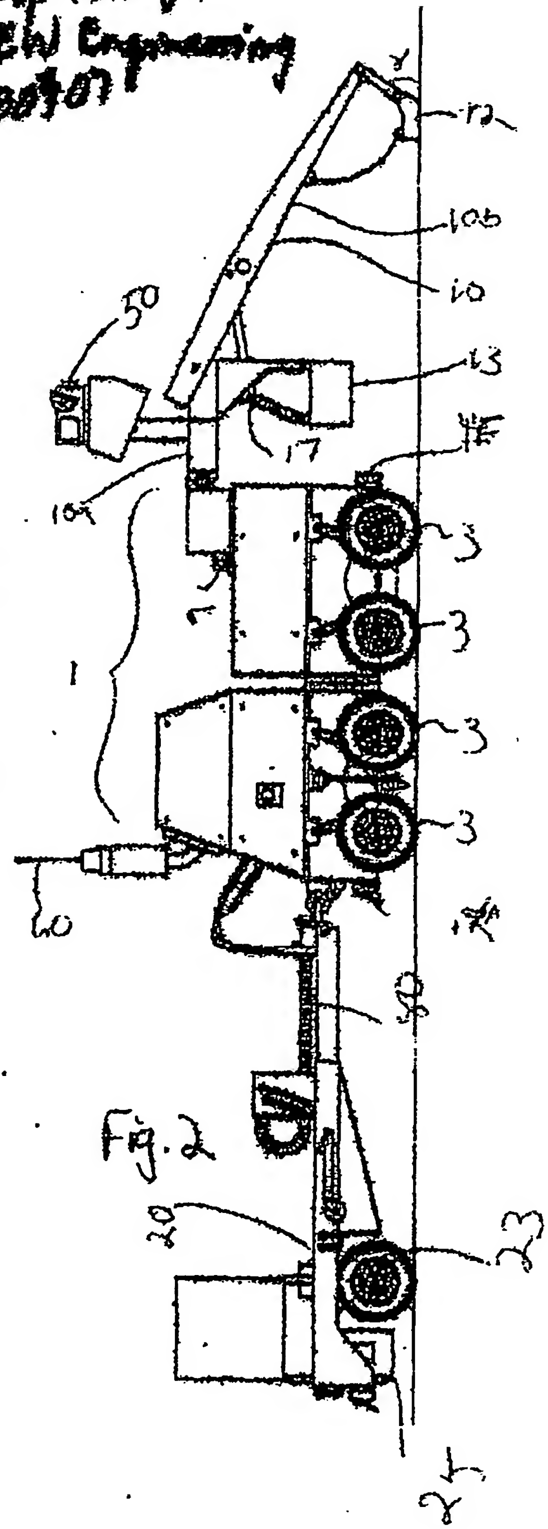

Fig. 2

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Rigging

OGW Engineering

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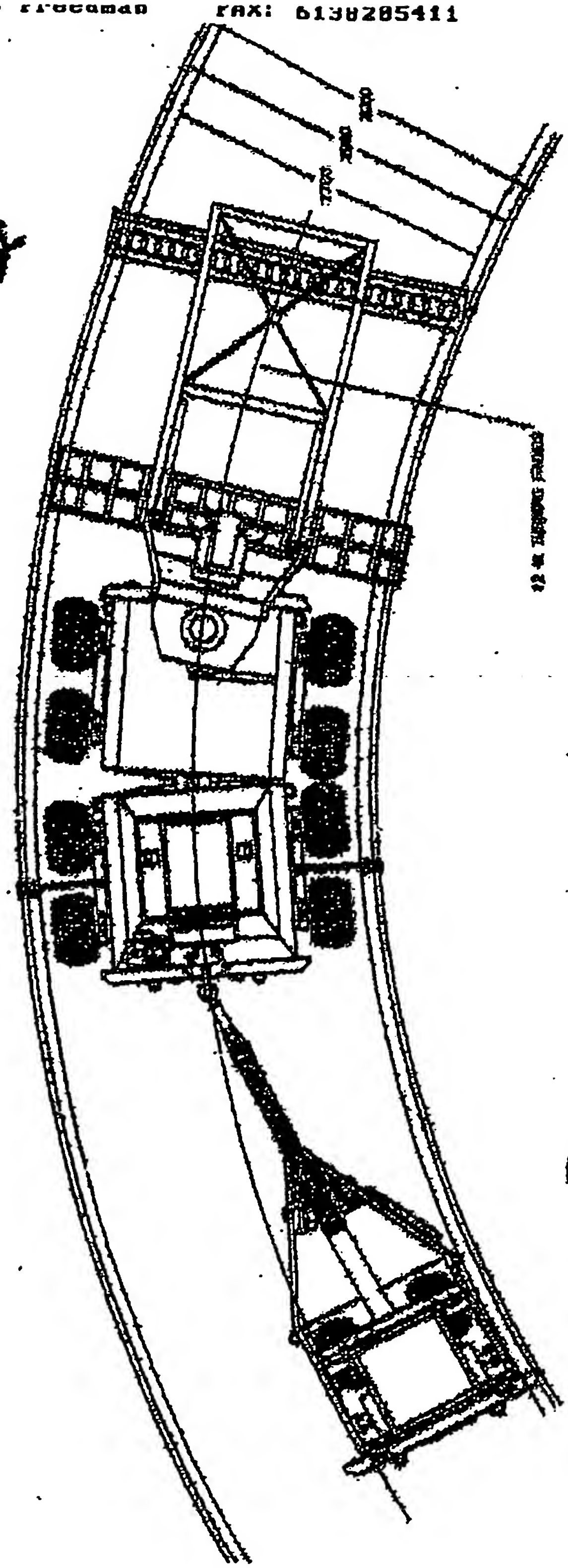

Fig. 3

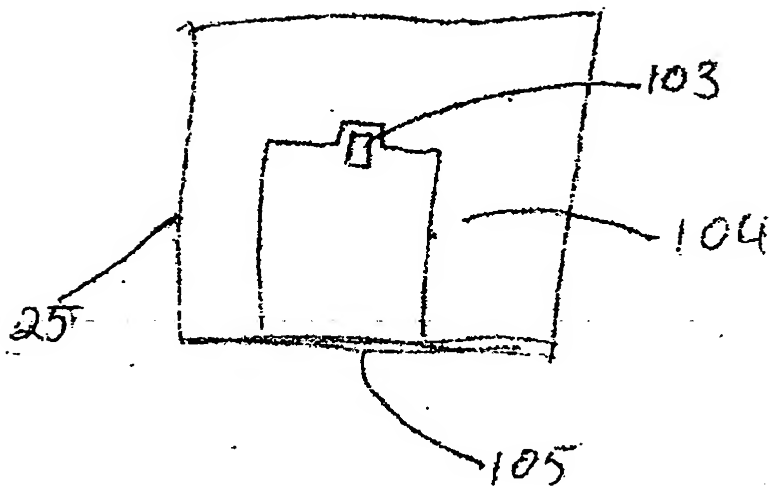

Fig. 4